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Predictors of Outcomes of Carpal Tunnel Release

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Objective. **To identify factors that are predictive of the outcomes of greatest importance to patients—i.e., symptom relief, functional improvement, and satisfaction with the outcomes of surgery—following carpal tunnel release.**

Methods. **We analyzed data from the Maine Carpal Tunnel Study, a community-based study of the outcomes of treatment for carpal tunnel syndrome. In a cohort of patients who underwent carpal tunnel release, a preoperative physical examination was performed and questionnaires were completed preoperatively and at 6, 18, and 30 months postoperatively. The questionnaires assessed symptom severity, upper extremity functional limitations, mental health, general physical health status, the relative severity of individual symptoms, satisfaction with the results of surgery, sociodemographic factors, and for those subjects who were in the workforce, aspects of the work environment. The associations between preoperative factors and the 3 principal outcomes (symptom severity, upper extremity functional limitations, and satisfaction with the results of surgery, all evaluated at 18 months postoperatively) were assessed with bivariate and multivariate linear regression and logistic regression analyses.**

Results. **Two hundred forty-one subjects were enrolled and 188 (78%) completed followup surveys 18 months postoperatively. Two-thirds of the patients reported being completely or very satisfied with the outcomes of surgery at 6, 18, and 30 months postoperatively. A range of clinical and work-related variables were associated with outcomes. In multivariate analyses, greater preoperative upper extremity functional limitation was predictive of greater functional limitations postoperatively. Worse mental health status was significantly associated with more severe symptoms and lower satisfaction. Alcohol use was also associated with more severe symptoms and lower satisfaction. Among workers, involvement of an attorney was significantly associated with greater functional limitation, more severe symptoms, and lower satisfaction. Recipients of worker's compensation who did not hire an attorney had generally good outcomes. Of note, physical examination parameters were not predictive of the outcomes of surgery.**

Conclusion. **The outcomes of carpal tunnel release in community-based practices are excellent. Predictors of the outcomes of surgery are disease-specific and generic clinical factors as well as work-related factors. The strongest predictors of less favorable outcomes are worse scores on patient-reported measures of upper extremity functional limitation and mental health status, alcohol use, and the involvement of an attorney. Clinicians should carefully evaluate patients' functional status, mental health status, health habits, and attorney involvement prior to performing carpal tunnel release, and discuss with patients the prognostic implications of these parameters.**

Patients with carpal tunnel syndrome (CTS) are typically managed with activity modification, wrist splints, antiinflammatory and/or analgesic medications, and, occasionally, injections of corticosteroids into the carpal canal. Patients who do not improve with these conservative measures are often referred for surgical decompression of the carpal tunnel. Approximately 250,000 to 300,000 carpal tunnel releases are performed annually in the United States (1). Surgery is performed with either an open or endoscopic approach and is

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reported to relieve symptoms in 70–90% of patients (2–6).

An accurate understanding of the factors predictive of the outcomes of carpal tunnel release would enable physicians and patients to make more informed decisions about whether to proceed with surgery, and to develop more accurate expectations of outcomes. Several studies have investigated the factors influencing the outcomes of carpal tunnel release. Worse outcomes of surgery have been associated with preoperative muscle weakness or atrophy (4,7,8), worker's compensation (9,10), predisposing medical conditions (4) including diabetes and thyroid disease (11), heavy or repetitive manual work (12,13), exposure to vibration (14), incorrect diagnosis (15), and incomplete sectioning of the transverse carpal ligament (15). Predictors of favorable surgical outcomes include prominence of paresthesia (rather than numbness or weakness [16]) and favorable response to corticosteroid injection (4,17). The duration of symptoms has not been associated with outcomes in some studies (4,12,18), but a longer duration has portended worse outcomes in other studies (7,8,11). Although the severity of nerve conduction or electromyographic abnormalities has generally not been associated with outcomes (4,7,12,13), Higgs and colleagues reported less symptom relief in workers with normal or near normal electrophysiologic parameters than in subjects with nerve conduction tests indicative of CTS (19). Also, Harris and colleagues showed that patients with the greatest prolongation in nerve conduction latencies across the carpal tunnel had the most complete pain relief (18). Overall, these prior findings point to a multidimensional predictive model of surgical outcomes, in which clinical, workplace, and economic factors influence the results of carpal tunnel release.

The published literature on predictors of the outcomes of surgery has important methodologic limitations. Many studies have utilized retrospective designs, precluding meaningful analysis of preoperative factors such as patient-reported symptom severity, functional status, and mental health. Also, few studies have used standardized measures of the outcomes that matter most to patients—relief of symptoms, reduction in functional limitations, and satisfaction (20,21). Studies have typically considered a narrow range of potential predictors that are focused primarily on the prognostic value of physiologic impairment measures, such as abnormalities on electrophysiologic testing and physical examination. Many studies have been conducted in referral centers and thus are subject to referral bias, whereas most carpal tunnel releases are performed in community practices.

This analysis of preoperative factors associated with the clinical outcomes of carpal tunnel release overcomes many of the limitations of prior research because it is community-based and tests a multidimensional model of the predictors and patient-reported outcomes of carpal tunnel release. The goal of the analyses presented here is to identify preoperative factors associated with the outcomes of carpal tunnel release, including symptom severity, functional limitation, and patient satisfaction with the results of surgery. We hypothesized that several distinct factors are predictive of surgical outcomes, including the severity of preoperative symptoms and functional limitations, aspects of the clinical presentation (such as bilaterality of symptoms), psychological and social factors, and for those patients in the workforce, physical exposures and economic factors. For most outcomes, we anticipated that these distinct factors have independent prognostic effects.

PATIENTS AND METHODS

Data source. The Maine Carpal Tunnel Study (1,10) is an observational, community-based effectiveness study of the outcomes of nonoperative and surgical treatment of CTS. The present report focuses exclusively on the cohort of patients who were scheduled for surgery at the time of enrollment.

Physicians. All twenty-five surgeons in the state of Maine who performed >20 carpal tunnel releases in 1991 were invited to participate in the study, of whom 16 (64%) accepted. Ten other surgeons with a lower annual caseload were also invited and agreed to participate.

Patients. Patients were eligible if they met all of the following criteria: 1) they had paresthesia involving at least 2 fingers (the thumb, index, middle, and ring fingers); 2) the duration of symptoms exceeded 1 month; 3) the treating physician's diagnostic impression was CTS; and 4) the patient was scheduled for surgery between July 1992 and October 1993. Subjects were excluded if they were <18 years old, pregnant, unable to complete questionnaires because of cognitive or language difficulties, or had undergone prior carpal tunnel release in the same extremity. Nerve conduction tests were conducted in 93% of the subjects prior to surgery (results were not available because these tests were performed in laboratories throughout the state). Since this was an observational study and not a randomized trial, the surgical technique was not standardized. In general, patients received either conventional open carpal tunnel release with a longitudinal incision, or endoscopic release. The Brigham and Women's Hospital Human Investigations Committee approved the study and all subjects provided signed informed consent.

Data collection procedures. Trained study personnel administered baseline questionnaires and performed a standardized preoperative physical examination. Sixty-seven patients (28%) who could not be interviewed prior to surgery (because there was too little time between referral to the study

and the date of surgery) provided information on preoperative status during interviews conducted up to 4 weeks postoperatively. Physical examinations were not performed on these patients. Followup data were obtained by mailed questionnaire at 6, 18, and 30 months after surgery.

Data elements. We obtained sociodemographic, clinical, and work-related data on all patients.

Sociodemographic indicators. Sociodemographic indicators included age, sex, educational attainment, and health habits. The level of education was categorized as high school or lower versus some college or technical institute. Smoking status was categorized as smoking at the time of the preoperative evaluation or having quit <6 months previously, versus never smoked or having quit >6 months previously. Patients were also categorized according to whether they were drinking >2 drinks per day at the time of the preoperative evaluation.

Clinical status indicators. The principal outcomes were symptom severity, functional limitations of the upper extremity, and satisfaction with the results of surgery 18 months postoperatively. These outcomes were measured with reliable, valid scales (hereafter referred to as the symptom severity, functional limitation, and satisfaction scales) described in detail elsewhere (21,22). Each item in these scales has 5 ordinal response categories, ranging from 1 (no symptom, no difficulty, completely satisfied) to 5 (very severe symptoms, so difficult could not do activity, very dissatisfied). The items are averaged with equal item weighting to yield the scale score, which ranges from 1 to 5. The symptom severity scale refers specifically to the operated extremity, while the functional limitation scale asks about ability to perform activities without reference to use of a specific extremity. The symptom severity and functional limitation scales each have been shown to have Cronbach's alpha reliability coefficients of 0.89 and the satisfaction scale has a Cronbach's alpha of 0.95 (21,22). In addition to the summary scale, we also present patient's responses to the single item regarding their overall satisfaction with the results of surgery (the 5 possible responses included completely, very, or somewhat satisfied, or somewhat or very dissatisfied).

The 18-month assessment afforded a longer period of followup than did the 6-month assessment, and a slightly larger sample than that at the 30-month assessment. Also, outcomes at 6, 18, and 30 months were highly correlated (10), with correlation coefficients for the associations between 6-, 18-, and 30-month values of each principal outcome (symptom severity, functional status, and satisfaction) ranging from 0.64 to 0.86.

We created a relative severity measure for each symptom by dividing the patient's rating for that symptom by the patient's total symptom severity score. For example, the relative severity of tingling was calculated as the patient's rating of the severity of tingling divided by the patient's total symptom severity score (both numerator and denominator ranged from 1 to 5). A score >1 would indicate that tingling was particularly prominent relative to the other symptoms.

Physical impairment was assessed with grip strength, thenar atrophy, 2-point discrimination, Semmes-Weinstein monofilament sensibility, and the Tinel and Phalen signs. These tests were performed on the operated hand as reported previously (10). Grip strength was reported in kilograms. Two-point discrimination was tested 3 times each in the index and middle fingers according to a defined protocol and quantified as the number of stimuli perceived incorrectly. Semmes-Weinstein monofilaments (filament numbers 2.83, 3.61, and 4.31) were applied 3 times each to the index and middle fingers and the number perceived correctly was categorized as 0–6, 7–12, and 13–18.

Patients also completed the Medical Outcomes Study 36-item Short Form health survey (SF-36) (23), a generic measure of health status. For these analyses, we investigated the physical component score, which reports aspects of physical health status (24), and the mental health subscale score, which measures depression and anxiety (25). Comorbidities included a wide range of medical problems and were summed without weighting.

Work-related indicators. Patients were classified as worker's compensation recipients if worker's compensation insurance was the principal payer for care related to CTS. Patients were classified as having an attorney if an attorney was involved preoperatively. Because attorneys were used exclusively by workers receiving worker's compensation, we created a 3-level variable: receiving worker's compensation and involved with an attorney, receiving worker's compensation and not involved with an attorney, or neither receiving worker's compensation nor involved with an attorney. Occupation was classified according to the 1980 US Census code classification, and trichotomized as managers and professionals (codes 003–199), machine operators, fabricators, and laborers (codes 704–889), or other. Exposure to upper extremity physical stressors at work was assessed with 2 scales previously developed by us, of which 1 measures exposure to keyboard work and the other, exposure to repetitive, forceful activities (26).

Statistical analysis. Associations between the principal outcomes at 18 months and preoperative predictor variables were examined with the Wilcoxon rank sum test for categorical predictors and the nonparametric Spearman's correlation coefficient for continuous predictors. We introduced all predictor variables with bivariate significance levels less than 0.10 into multivariate linear regression models. We initially modeled individual clusters of variables (sociodemographic, clinical, work-related) against each outcome. We then took all of the significant ($P = 0.10$) predictors of outcome within each cluster and advanced them to final models. We ran final models with and without stepwise selection procedures (which limit the model to just those variables that contributed to the outcome at $P \leq 0.15$). These 2 approaches identified the same statistically significant predictor variables, with generally similar magnitudes of effect. We present the models from stepwise selection for ease of interpretation. To convey the strength of association, we report the standardized regression coefficients. This parameter represents the change in the dependent variable associated with a change of 1 SD in the predictor variable. Since preoperative symptom severity and upper extremity functional limitation were highly correlated ($r = 0.65$), we included just one of them, upper extremity functional limitation, in the models. Mean substitution was used to impute missing values for age (20 patients had missing values for age; separate means were imputed for those in the workforce and for others, since the workers were generally younger). No other variables had substantial missing data.

A range of work-related variables could only be tested meaningfully among patients who were either working or out

Table 1. Functional status, symptom severity, and satisfaction with carpal tunnel release in the Maine Carpal Tunnel Study*

	No. of patients	Functional limitation score, mean ± SD	Symptom severity score, mean ± SD	Dissatisfaction with surgery score, mean ± SD	% very or completely satisfied	% somewhat satisfied	% dissatisfied
Preoperative	241	2.8 ± 0.9	3.3 ± 0.8	NA	NA	NA	NA
6 months	203	1.8 ± 0.8†	1.8 ± 0.8†	2.1 ± 1.0	66	20	14
18 months	188	1.7 ± 0.8†	1.8 ± 0.8†	2.1 ± 1.0	66	21	12
30 months	186	1.8 ± 0.9†	1.8 ± 0.9†	2.1 ± 1.1	67	20	14

* Some data were not available (NA) because satisfaction with surgery was not ascertained until the postoperative surveys. Percentages do not add up to 100 because of rounding. Symptom severity, functional limitation, and dissatisfaction scores range from 1 (least severe symptoms, least limitation, most satisfied) to 5 (most severe symptoms and functional limitation, least satisfied).
† Improvements between preoperative and followup scores were statistically significant at $P < 0.0001$.

of work because of CTS at the time of surgery. Thus, we developed one set of models for the entire cohort and a separate set for this subgroup, which included work-related predictor variables such as whether an attorney was involved and exposure to repetitive, forceful occupational activity.

We also performed a longitudinal analysis that incorporated outcome data from all 3 followup intervals (6, 18, and 30 months) to assess whether time after surgery was a predictor of the principal outcomes, after adjustment for covariates. These analyses were performed using the Generalized Estimating Equations method implemented through Proc Genmod in SAS (27). The results of this longitudinal analysis did not suggest that time since surgery had a significant effect on outcomes. Therefore, we present results from the 18-month analysis.

Finally, we analyzed the data with logistic regression models. For each linear regression model, we dichotomized the continuous variables by distinguishing the bottom quartile from the rest of the patients. The independent variables included all of the terms that were significant predictors of outcomes in the linear regression models. The results were similar to the linear regression findings, and are therefore not presented.

Statistical analyses were performed with the SAS statistical package (28). All P values were 2-tailed.

RESULTS

Results of patient recruitment. Two hundred forty-one subjects (92% of those eligible for this study) completed preoperative questionnaires. Of these, 188 (78%) completed followup surveys 18 months after surgery. The 22% who did not complete surveys at 18 months did not differ significantly from those that continued to participate with respect to sex, symptom severity, or functional limitation scores at baseline ($P >$ 0.20 for each). Worker's compensation recipients were less likely to complete questionnaires at 18 months (67% of worker's compensation recipients versus 85% of nonrecipients completed questionnaires; χ^2 [1 degree of freedom (df)] = 9.5, $P = 0.002$), and younger patients were more likely to drop out (mean age 51 years in those who remained in the study versus 42 years in those who dropped out; Kruskal-Wallis χ^2 [1 df] = 14, $P = 0.0001$). Twenty-eight patients who did not complete questionnaires at 18 months participated at 6 months; the satisfaction and functional status scores of these patients did not differ significantly from those who returned questionnaires at 18 months. However, the patients who did not complete questionnaires at 18 months had worse symptom scores at 6 months (mean 2.2) than did those who completed the questionnaires (mean 1.8; Kruskal-Wallis χ^2 [1 df] = 7.4, $P = 0.007$). As reported previously (10), patients enrolled in the study did not differ in their demographic features or outcomes (symptom relief, functional status, and satisfaction) at 18 months from those who were eligible but were not invited to participate.

Some of our analyses are relevant only to the subset of patients who were either working or out of work due to their CTS at the time of enrollment. One hundred seventy-one patients were in this subset, of whom 130 (76%) completed questionnaires at 18 months.

The mean age of patients enrolled in the cohort was 44.6 years (median 43.0 years, SD 11.5) and 66% were female.

Surgical outcomes. Patients improved markedly by 6 months following surgery, and maintained their improvement throughout the 30-month followup period (Table 1). Symptom severity scores improved from an average of 3.3 preoperatively to 1.8 at 18 months, and functional limitation scores improved from 2.8 to 1.7. These differences between preoperative and followup symptom severity and functional limitation scores were highly statistically significant ($P < 0.0001$ for both). The proportion of patients indicating that they were very or completely satisfied with the results of their surgery was 66%, 66%, and 67% at the 6-, 18-, and 30-month followup assessments, respectively (Table 1).

Table 2. Univariate correlations (Spearman's r) between continuous predictor variables and outcomes at 18 months following carpal tunnel release in the Maine Carpal Tunnel Study*

Preoperative predictor variable	Symptom severity	Functional limitation	Dissatisfaction with surgery
Grip strength	−0.14	−0.10	−0.21†
Better 2-point discrimination	−0.08	0.01	−0.04
Age	−0.19†	−0.12	−0.18†
Duration of symptoms	0.09	0.07	0.01
Comorbid conditions	0.01	0.02	0.02
Symptom severity score	0.20†	0.20†	0.18†
Upper extremity functional limitations score	0.24‡	0.42‡	0.22‡
Physical health score, SF-36	−0.21‡	−0.25‡	−0.22‡
Mental health (MHI-5) score	−0.23‡	−0.22‡	−0.24‡
Prominence of specific symptoms§			
Night pain	−0.05	−0.03	−0.06
Numbness	−0.08	−0.09	−0.03
Day pain	0.22‡	0.20†	0.15†
Tingling	−0.03	−0.05	−0.02
Exposure to keyboard activities	−0.22†	−0.09	−0.14
Exposure to physical stressors	0.19†	0.19†	0.19†

* Symptom severity, functional limitation, and dissatisfaction scores range from 1 (least severe symptoms, least limitation, most satisfied) to 5 (most severe symptoms and functional limitation, least satisfied). Physical health and mental health scores range from 0 (worst) to 100 (best). SF-36 = Medical Outcomes Study 36-item Short Form; MHI-5 = 5-item Mental Health Interview.
† $P < 0.05$.
‡ $P < 0.005$.
§ Prominence of a specific symptom calculated as the rating for that symptom divided by the symptom severity score.

Predictors of outcomes. Bivariate associations between preoperative features and outcomes are shown in Table 2 for continuous preoperative predictor variables, and in Table 3 for categorical preoperative variables. Older patients had less severe symptoms and greater satisfaction at followup. Outcomes did not vary by sex. Among the clinical variables, none of the physical examination measures (thenar atrophy, grip strength, Tinel sign, Phalen sign, 2-point discrimination, Semmes-Weinstein monofilaments) had significant associations with outcomes, except that preoperative grip strength was marginally associated with satisfaction with surgery ($r = -0.21$, $P = 0.03$). Higher preoperative symptom severity and functional limitations and lower mental health status and physical health status (as measured with the SF-36 physical component subscale) were all associated with worse outcomes following surgery (Table 2).

Among work-related variables, involvement of an attorney portended worse outcomes after surgery. Those who were receiving worker's compensation but were not involved with an attorney had outcomes similar to those who were not receiving worker's compensation. Operators, fabricators, and machine operators also had worse outcomes (Table 3). Similarly, subjects exposed to repetitive, forceful exertions had worse outcomes, whereas those who were more intensively exposed to keyboard activities had better symptom status (Table 2).

To illustrate more clearly the effect of preoperative functional limitations and having an attorney, we dichotomized functional limitations into the lowest quartile and upper 3 quartiles. In the cohort who were in the workforce, 59% of subjects in the worse quartile of functional limitation scores preoperatively were also in the lowest quartile for functional limitations postoperatively. In contrast, 15% of those in the upper (best) 3 quartiles preoperatively were in the lowest quartile postoperatively ($P < 0.0001$). Similarly, 65% of subjects who had an attorney versus 18% of subjects without an attorney were in the lowest quartile of functional limitations at 18 months ($P < 0.0001$).

Multivariate models. In multivariate linear regression analyses involving the entire cohort, greater preoperative functional limitation was the most important predictor of greater functional limitation 18 months postoperatively (Table 4). Smokers also had worse functional outcomes. Several preoperative factors were predictors of more severe symptoms at followup, all at marginal P values ($0.03 \leq P \leq 0.08$). These included tobacco and alcohol use, worse mental health status, prominent day pain, and bilateral symptoms. Worse preoperative mental and physical health status were

Table 3. Univariate associations between categorical predictor variables and outcomes at 18 months following carpal tunnel release in the Maine Carpal Tunnel Study*

Preoperative predictor variable	No. of patients†	Symptom severity (mean score)	Functional limitation (mean score)	Dissatisfaction with surgery (mean score)
Thenar atrophy present	25	1.7	1.7	2.1
Thenar atrophy absent	95	1.9	1.8	2.2
Tinel sign present	60	2.0	1.9	2.2
Tinel sign absent	41	1.7	1.7	2.1
Phalen sign present	85	1.8	1.8	2.1
Phalen sign absent	25	1.9	2.0	2.2
Semmes-Weinstein category				
0–6	36	1.8	1.7	2.1
7–12	50	1.9	1.9	2.3
13–18	35	1.8	1.9	2.1
Bilateral symptoms	118	1.9	1.8	2.2
Unilateral symptoms	67	1.6‡	1.6§	1.9
Endoscopic release	46	1.7	1.7	2.1
Open release	135	1.8	1.8	2.1
Females	130	1.7	1.8	2.1
Males	58	1.9	1.6	2.2
High school or lower	104	1.8	1.8	2.2
At least some college	84	1.7	1.7	2.0
Married	134	1.8	1.7	2.1
Not married (single, divorced, widowed)	54	1.7	1.9	2.1
Live alone	22	1.8	1.8	2.1
Live with others	165	1.8	1.7	2.1
Smoker	58	2.1	2.0	2.4
Nonsmoker	130	1.7§	1.6‡	2.0§
Drinker	23	2.1	1.9	2.7
Nondrinker	165	1.7	1.7	2.0§
Diabetes	20	1.7	1.7	2.2
No diabetes	168	1.8	1.7	2.1
No worker's compensation or attorney	73	1.7	1.6	1.9
Worker's compensation, no attorney	35	1.9	1.8	2.2
Worker's compensation plus attorney	18	2.6¶	2.6¶	2.9‡
Managerial occupation	30	1.8	1.6	2.1
Laborer occupation	19	2.2§	2.1§	2.6§
Other occupation	81	1.7	1.7	2.1

* The symptom severity, upper extremity functional limitation, and dissatisfaction scales each range from 1 to 5, with 1 representing the best score (no symptoms, no difficulty, completely satisfied) and 5, the worst score (very severe symptoms, cannot do at all because of hand or wrist symptoms, very dissatisfied).
† n = 188, except for worker's compensation/attorney and occupation categories. For these variables, analyses were restricted to the 130 subjects in the workforce or out of work because of carpal tunnel syndrome. n = 121 for physical examination variables, since 67 did not have physical examinations (see text).
‡ $P < 0.005$, by Kruskal-Wallis test.
§ $P < 0.05$, by Kruskal-Wallis test.
¶ $P < 0.0005$, by Kruskal-Wallis test.

Table 4. Covariate-adjusted standardized regression coefficients and goodness of fit for linear regression models of associations between predictors and outcomes of carpal tunnel release 18 months after surgery in the entire cohort (not including work-related variables)*

	Upper extremity functional limitations (n = 172)		Upper extremity symptom severity (n = 185)		Dissatisfaction with surgery (n = 188)	
Preoperative predictor variables	Standardized beta†	*P*	Standardized beta†	*P*	Standardized beta†	*P*
Upper extremity functional limitations	6.3	0.0001	2.5	0.02		
Mental health status			−1.8	0.08	−3.3	0.001
Physical health status (SF-36)					−3.3	0.001
Tobacco use	2.9	0.004	1.9	0.06		
Alcohol use			2.0	0.05	3.1	0.002
Day pain prominent			2.2	0.03		
Bilateral symptoms			2.2	0.03		
Model R^2	0.23		0.19		0.15	

* Symptom severity, functional limitation, and dissatisfaction scores range from 1 (least severe symptoms, least limitation, most satisfied) to 5 (most severe symptoms and functional limitation, least satisfied). Physical health (on the Medical Outcomes Study 36-item Short Form [SF-36]) and mental health scores range from 0 (worst) to 100 (best).
† Calculated as the beta coefficient from the regression model divided by the standard error of the beta coefficient.

predictive of lower satisfaction with surgery, as was use of alcohol.

The most striking finding of the multivariate linear regression models among subjects who were either working or out of work due to CTS preoperatively was the poor prognostic influence of having an attorney (Table 5). Aside from the attorney effect, significant predictor variables identified in these models were similar to those identified for the entire cohort (Tables 4 and 5). Greater preoperative functional limitation was the most powerful predictor of postoperative functional limitation. Patients who performed forceful, repetitive work, those with bilateral symptoms or prominent day pain, and those who used alcohol had more severe symptoms postoperatively. The strongest predictor of lower satisfaction was alcohol use. We assessed for interactions between baseline function and tobacco use in the model of functional status in the entire cohort, and the interaction between baseline functional status and having an attorney in the model of functional status in the workers' cohort. Neither interaction was statistically significant.

Table 5. Covariate-adjusted standardized regression coefficients and goodness of fit for linear regression models of associations between predictors and outcomes of carpal tunnel release 18 months after surgery in subjects in the workforce (including work-related variables)*

	Upper extremity functional limitations (n = 111)		Upper extremity symptom severity (n = 115)		Dissatisfaction with surgery (n = 116)	
Preoperative predictor variables	Standardized beta†	*P*	Standardized beta†	*P*	Standardized beta†	*P*
Upper extremity functional limitations	4.9	0.0001	2.4	0.02	1.4	0.15
Mental health status	−2.3	0.02			−2.3	0.02
Physical health status (SF-36)					−2.0	0.04
Alcohol use			2.4	0.02	2.7	0.008
Prominent day pain			2.1	0.04		
Bilateral symptoms			3.2	0.002		
Attorney involved	3.2	0.002	2.9	0.005	1.8	0.07
Forceful, repetitive work			3.2	0.002		
Model R^2	0.38		0.37		0.27	

* Symptom severity, functional limitation, and dissatisfaction scores range from 1 (least severe symptoms, least limitation, most satisfied) to 5 (most severe symptoms and functional limitation, least satisfied). Physical health (on the Medical Outcomes Study 36-item Short Form [SF-36]) and mental health scores range from 0 (worst) to 100 (best).
† Calculated as the beta coefficient from the regression model divided by the standard error of the beta coefficient.

DISCUSSION

In this community-based study of the outcomes of carpal tunnel surgery, the most important independent predictor of upper extremity function 18 months postoperatively was preoperative upper extremity function. A range of variables were predictors of symptom severity 18 months postoperatively, including aspects of the preoperative symptom complex—bilateral symptoms and prominence of day pain. In contrast, satisfaction with the surgery was predicted by the presence, preoperatively, of variables that were not directly related to the upper extremity, including general physical function, mental health, and alcohol use. Involvement of an attorney was strongly predictive of more severe symptoms and functional limitations among patients who were working (or out of work due to CTS) preoperatively. Overall, variables from each of the 3 clusters—sociodemographic (health habits), clinical, and work-related—were associated with 1 or more outcomes, supporting the hypothesized multidimensional model.

A key result of our work is the observation that direct physical examination measures of median nerve dysfunction, such as Semmes-Weinstein monofilament testing and 2-point discrimination, had virtually no association with surgical outcomes. Thus, while the physical examination is useful for diagnosis and assessment of median nerve impairment, it has little utility for predicting postoperative functional limitation, symptoms, or satisfaction—the key indicators of successful surgery from the patient's point of view (20,29). Others have found that thenar atrophy is predictive of a poor outcome (4,7,8). We did not find this association, but would note that atrophy is difficult to measure reliably.

Our findings underscore the crucial prognostic role of patient-reported measures of health status (such as physical and mental health status and disease-specific functional limitations). This concurs with our recent findings that patient-reported preoperative health perceptions are strong predictors of the outcomes of surgery for degenerative lumbar spinal stenosis (30), and that preoperative functional status is a strong predictor of the outcomes of total knee and hip arthroplasty (31). Similarly, Pincus and colleagues have shown that self-reported functional status is predictive of subsequent mortality among patients with rheumatoid arthritis (32). Taken together, these observations indicate that a patient's self-reported health status is a powerful predictor of future health status following a range of treatments and across a range of conditions.

Involvement of an attorney was associated with worse outcomes, suggesting that patients are less likely to improve while legal issues (generally related to a worker's compensation claim) are being contested. The mechanism for this effect merits further study. The involvement of an attorney may be a marker for more severe cases or physical or psychosocial work exposures that exacerbate symptoms. It is also conceivable that patients over-report their symptoms and functional limitations in the setting of a contested claim. Given that attorney involvement was generally related to a disputed claim, it may be that the dispute over compensability, and not the attorney per se, is the key prognostic factor. A related, important finding of this study is that worker's compensation status was not associated with significantly worse outcomes unless an attorney was involved. This finding helps to refine our understanding of the possible mechanisms for the worse prognoses associated with worker's compensation in prior studies (9), and underscores the importance of efforts to reduce disputes surrounding worker's compensation claims.

Greater self-reported exposure to repetitive motions and force was associated with worse symptoms. This finding is consistent with observations in prior reports (12). We do not have sufficiently detailed data to discern whether this was due to the effects of the exposure preoperatively or to the worker returning to the same physical exposure postoperatively, or to both.

The observation that patients with prominent daytime symptoms preoperatively have more severe postoperative symptoms suggests that daytime pain may signal the co-occurrence of other soft tissue disorders that do not respond to carpal tunnel release. This finding concurs with prior reports showing that day pain and numbness were less responsive to surgery than were symptoms of acute nerve irritation such as nocturnal pain and tingling (16). Similarly, since unilateral carpal tunnel release does not relieve contralateral symptoms, it is logical that patients with bilateral involvement would remain symptomatic postoperatively.

The associations between use of alcohol and tobacco and the outcomes of carpal tunnel release documented here deserve further study. While it is possible that these exposures influence outcomes through a direct toxic effect on the median nerve, it is more likely that they are surrogates for unmeasured lifestyle or clinical factors. Alcohol use was not associated with education level, type of job, physical exposure to force and repetition, or physical or mental health status (data not shown), indicating that the effect of alcohol was not due to residual confounding by one of these other variables.

The methodologic strengths of this study include the community-based sample, high rate of participation, acceptable rate of subject retention at followup, use of reliable and valid measures, and availability of potential predictors across numerous domains, including sociodemographic, clinical, and work-related factors.

Several limitations must also be acknowledged. Virtually all patients were white, potentially limiting generalizability. Twenty-eight percent of patients could not be reached until 0–4 weeks postoperatively, raising the possibility of inaccurate recall or response shift (33) and precluding physical examination. The key predictor variables were all self-reported and potentially vulnerable to bias. Furthermore, because we did not have raw data on nerve conduction testing, we cannot comment on whether nerve conduction abnormalities are independent predictors of outcomes. Similarly, we had a relatively constrained set of potential workplace psychosocial predictors. Data on workplace organizational policies and practices, perceived job strain, social support at work, and other factors might have shed further light on the determinants of surgical outcomes.

Finally, although 93% of subjects had undergone nerve conduction testing, electrophysiologically documented median neuropathy was not required for entry into the study. The modest diagnostic value of the history (and physical examination) gives rise to potential methodologic limitations (34). A recent Swedish population-based prevalence study showed that only 45% of adults with the typical symptoms of pain, numbness, and tingling in the median nerve distribution had electrophysiologic evidence of median neuropathy (35). A community-based survey in the United Kingdom also documented that symptoms occurred commonly in the median nerve distribution in the absence of electrophysiologic evidence of CTS (36). Furthermore, symptoms in the median nerve distribution are variable over time (37). These observations all point to the potential for misclassification in studies of CTS that use symptom-based diagnostic criteria without electrophysiologic confirmation. We acknowledge this limitation, but suspect it did not play a major role in our sample. These previous population-based studies had CTS prevalences in the range of 2%, while in our study, all patients were presumed to have CTS, which was severe enough to warrant carpal tunnel release. Therefore, since prior probability (prevalence) strongly influences the positive-predictive value, the positive-predictive value of median nerve symptoms in our sample was likely to be much higher.

Our findings have important implications for clinical practice and future research. Clinicians should incorporate these results in their discussions with patients regarding the likely outcomes of carpal tunnel release. Patients should understand that worse preoperative functional limitation of the hand and worse overall physical health status and mental health status, as well as involvement of an attorney, all portend a less favorable outcome. Similarly, alcohol use, bilateral symptoms, and prominent daytime symptoms are associated with more severe symptoms postoperatively. This does not imply that patients with these risk factors should be denied surgery; rather, the patient and clinician should acknowledge that for complex reasons, outcomes are typically worse in the presence of these factors.

From a research perspective, our findings raise additional questions. Clinical trials could begin to address whether improving preoperative mental health or functional status of the hand, or operating on patients earlier in the course of the functional decline associated with CTS would improve outcomes. Further research should also examine alternative methods of dispute resolution other than hiring attorneys to contest worker's compensation decisions. Worker's compensation reforms in Maine and some other states over the last decade have attempted to reduce the number of disputed cases. The effect of these changes on the outcomes of carpal tunnel surgery (or other procedures) should be evaluated. Finally, additional research on an even broader range of potential personal and workplace factors associated with outcomes could further enhance our ability to predict the results of surgery.

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